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From a Cognitive Model Towards an Assistive and Augmentative Written Language

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Abstract

This paper presents a discussion about assistive and augmentative natural language processing designed for certain disabled persons unable to communicate.
Several approaches have been proposed, according to abilities of the writer. Here we distinguish two cases in the writer's capacities: the writer knows alphabetic writing, or (s)he does not know it. In the first case, the idea is to assist the writer by completing the words or the group of words which are initially written. In the second case, pictograms are used instead of characters, but it must be decided if these pictograms represent concepts or words in a new writing system. If the pictograms represent concepts, the produced text may not correspond exactly to the wishes of the writer; whereas when the pictograms represent words, the writer has to change his (her) mental approach to write the words that (s)he has chosen in another way.

A new application of natural language processing

If the compilation of increasingly sophisticated computer languages ensures that the machine will perform the operations described by a high level language, it is not the case for natural language processing. Automatic processing of natural languages rises complex problems of adjustment between the user and the machine at different levels, on which the machine does not "understand" yet the natural language as humans do: for instance, human-machine dialogue, search by keywords, querying databases, text mining, and automatic understanding of texts..

However, it is doubtful whether the understanding by the machine is necessary for many applications. If the machine is used as an augmentative capacity to partially compensate a user's disability of language, the problem may be conceptualized otherwise, and the possibility of a cognitive model can be very useful.

Texts are generally stored as character strings without any semantic representation built by the machine. In some applications, texts are organized according to domain ontologies, but this method of organization is useful only for certain types of restricted treatment. The different approaches proposed for dealing with natural language show that the cognitive and semantic problem remains. Therefore, the target of the user must be known in order to adapt a mode of language processing that can answer the given problem: n-grams (Boissière et al. 2006) Finite State Automates (FSA), or more cognitive methods overlaying our linguistic process, have been studied.

Taking as starting point a problem of disability relieved by assisted writing, we discuss the use of different approaches such as n-grams, FSA, glossary of phrases or cognitive methods.

Context: severe difficulties to write

We have described problems of pictographic palliation of communication disability in several articles[1]. Here, we show how an adapted syntactic typing and a good cognitive design of pictograms are necessary to offer disabled persons a method that helps them to write a text. First, we must understand and know what characterizes the disability, then find the "toolbox" of NLP (Natural Language Processing) to provide the most appropriate assistance.

[1](Abraham 2000a), (Abraham 2000b), (Abraham. 2007), (Abraham 2008).

If the disabled persons can read, they can use devices which propose letters or words on virtual keyboards in a way adapted to their motor skills. However, the writing process remains often slow. To cope with the issue, it has been attempted to predict the written text by complementing the words or proposing sentence fragments from the letters already written. Such help is possible if certain patterns of words are frequently used in a set of predefined contexts (Boissière et al. 2006).

In these predictive systems, either the language model is built on a large corpus of texts, or a means to learn new words is possible to extend the available models. In closed contexts, the style of sentences provides some sort of a profile of the writer.

Another possible case arises if the handicapped person knows what (s)he wants to write, but cannot use alphabetic writing. Then pictograms are proposed to replace the alphabetic writing, with the naive assumption that words are better recognized if a drawing of the entity they represent is given. In this case, the purpose of assisting writing consists of processing a series of pictograms in one sentence of text, but several conditions must be met for this to happen.

In summary, two cases are possible: either the writer wants to write alphabetic characters faster, to compensate for his(her) slowness, either (s)he must write what (s)he wants to say, using pictograms as the only linguistic processing input.

Assisted and augmented scripture

Alphabetic writing

In the case of alphabetic writing, the prediction is generally proposed to reproduce previously used structures, stored in a lexicon of phrases. From a semantic point of view, this approach can be denoted as mimetic. Several models of treatment achieve this linguistic mimicry: they are local patterns from finite state automates, or statistical models based on n-grams.

The writer then controls the building of a sentence by reading the words or phrases which are proposed, and checks if the phrase that (s)he intended to write is correct. This writing task requires: i) using a device especially designed for an adapted configuration of a virtual keyboard: ii) reading what the treatment proposes in the text; iii) estimating that this is what (s)he wanted to write; iiii) do nothing if the text is correct, but if this text is not the appropriate one, it must be corrected. We then see that the improvement in writing rapidity is partly based on a good proposal for completion of words and text, and secondly, on the easiness to correct a text which is not suitable. If it works well, the control part of the writing task is not very tiring and the gain for the writer is appreciable. Otherwise, the task of correction may disturb the composition of the text. Instead of saving time, the writer can waste it.

<u>*Methods*</u>

Two methods based on the morpho-syntactic structures of the language are used: i) a method which learns words and phrases as typed, or which makes references to the texts of a same domain context stored in memory, based on states of local finite automates; ii) a method that has previously learned a large vocabulary and which is based on a statistical treatment by n-grams. Improvements of the method then depend on the size of n.At a practical level, in both cases, learning is necessary to control the new process of writing.

For the user, such a means of writing may give a heavier cognitive load, because of a dual task of managing his(her) text, while controlling the text proposals.

Pictographic writing

In the case of alphabetic writing being replaced by pictograms, we must first agree on the status of pictograms:

A pictogram represents concepts.

A concept refers to several synonymous words in a same semantic field (Blache, Ph. Rauzy, S.), but these words do not necessarily belong to the same syntactic category. Then, they do not use the same syntax when they are used in a sentence. Moreover, in this case, what is the entity which will be drawn as a pictogram? Let's take an example: if the concept refers to a computer device, this device can be a mouse, or a trackball, among others. The difficulty is to represent a device by a drawing. If the pictogram represents a mouse, which word will be associated to it? Probably "mouse", even if the user wanted to write "device". It is clear that this option cannot produce the proper text that the user wants to write. Generally, therapists propose that several words be associated to a same pictogram, including metonymy, and other syntactic categories as derived verbs or adjectives. The status of a pictogram is then ambiguous, concerning the entity to which its refers as well as the syntactic category to which it belongs.

A pictogram represents a word

A pictogram can represent a word of a syntactic category, but this word is often polysemic, as we say for the word *mouse*. Grammatically, polysemy is not upsetting (Figure 1), as all the useful grammatical features of a word are given in lexicon, but in terms of pictorial representation, it raises the question of the choice of the entity which represents a word which itself refers to several entities.

Discussion

If pictograms represent concepts, given that a concept can represent several words, a direct translation to text results in a not controlled lexicon. Besides, the only possible manner of building sentences is constrained, and can express something which may be far from the idea that the user wanted to communicate.

If each pictogram represents a single word, the set of pictograms can be considered as a new writing of the language, requesting a very precise pictorial representation of the semantics of each word and a good design of grammatical operations, in order to control the new way of writing the text. Therefore two conditions are to be respected: a good graphical design of the lexical or grammatical pictograms, and an adequate design of grammatical operations, which are more abstract. It is this new writing that we present here, along with some interesting cognitive problems it raises. Not pretending to be exhaustive, only some examples are given.

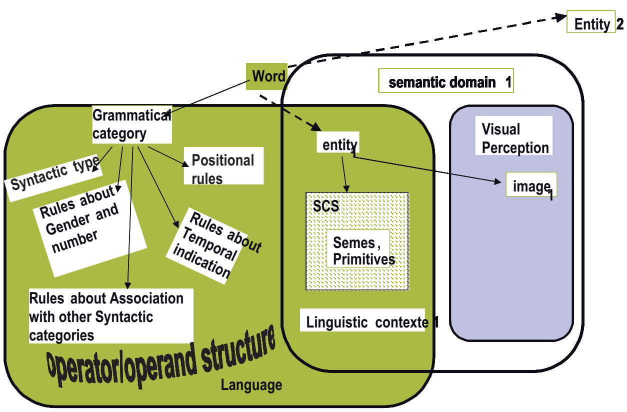

Figure 1: description of a polysemic word in the lexicon.

A cognitive model of the language

If a sequence of symbols is reduced to a sequence of labels, operations indicated by the grammar must be used to allow morphological changes given by the grammar, such as plurals, feminine, and conjugations. These morphological marks have a semantic value[2] necessary to understand a sentence.

The applicative and cognitive grammar (ACG)

The model of Applicative and Cognitive Grammar (ACG) was proposed by the LaLIC laboratory since 1985 (Desclés, J.P.), to overcome the lack of models patterned from the compilation of formal languages. A three-step model (linguistic, predicative, and cognitive levels) is proposed to analyze the language:

- The linguistic level, where we found flexed forms of words, as results of cognitive operations.
- The level of grammatical operations, given as predicates.
- The level of cognitive representations.

The model starts from the observed phenomena of an extra-linguistic world, and builds a computable formalism which is compatible with cognitive structures. The different structures are computerized from one step to the next.

At the cognitive level, we expect that there is a relation between the image and linguistic representations of situations. These situations can be described through sentences as well as complete scenes.

To enable the non-verbal user to understand the pictographic lexicon, the parts of discourse are first classified following syntactic criteria (nouns, verbs, adjectives, grammatical and operational functions) and each category is visualized through a specific colored frame, so that the image is contained in its syntactic category. Psychologist's observations assume that children use nouns (concrete entities) before verbs (which refer to changes), and that they have notions about these categories, even if the children cannot name them.

Inside each syntactic category, pictograms are then classified according to hierarchical semantic criteria. Verb representations are difficult to recognize. As they encode spatio-temporal modifications, they are represented by animated pictograms.

Grammar functions, graded according to grammatical difficulties, are also available, so that the whole language can be accessed and learned.

In the current use of the machine by paralyzed users, facilities as supplying defined articles[3] and conjugations are provided by the linguistic processing.

Since an ordered succession of pictograms does not build a sentence, each pictogram is associated to a word in a lexicon providing its grammatical type and features. These minimal indications are necessary to computerize the sentence, using the applicative and cognitive grammar[4]. Then, the sentence can be printed or sent to a vocal synthesis device or sent by e-mail.

[2] See (Langacker 1987), (Jackendoff 1983).

[3] Other determinations have to be explicit, given by a pictogram of grammar. We proposed to provide defined article, following latin language, to save gestures for paralyzed users.

[4] We do not detail here the typing (Desclés 1985), (Delamarre 2011) of the words, this articles focuses on semantic representations.

The ACG model reflects quite well our language behavior: the language that we understand is given at the observable level; successive grammatical operations are applied at the predicative level; the level of semantic definitions is invoked if the meaning of the words has to be understood or explained, as this meaning can be considered as compiled knowledge.

Cognitive approach of assisted writing

Building text from pictograms

A switch from an alphabetic to a pictographic writing means a new mental approach to build texts from thoughts. A virtual keyboard shows pictograms. As alphabetical order is irrelevant, we must find a presentation of hierarchical categories that simulate in some manner the writer's mental lexicon. The words are often polysemic : a given word can designate several different entities, the representations of which differ, depending on the context in which they are inserted.

So, we see here that the meaning of the pictograms is essential to find the words on the virtual keyboard showing the lexicon; then, once the pictogram is found, the meaning is no longer necessary to build a sentence; only the word and its grammatical type are necessary to construct a correct grammatical sentence.

Cognitive representation of words

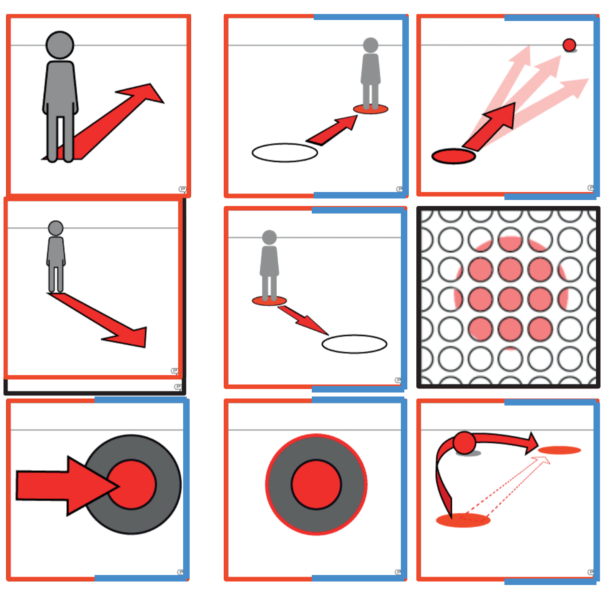

Figure 2 : Some verbs and prepositions.

After having chosen the most representative entity named by a word, this entity has to be visually represented, showing only its main features, properties and attributes which are specific to the meaning of the word, and which can distinguish this word from another one close to it inside a semantic category. The problem is quite difficult concerning certain words, as verbs, adjectives, grammar operations and prepositions. We give here the representation of a few French verbs, prepositions, and articles, the pictogram of which are closed to each other. See Figure 2, from left to right and top to bottom: *aller, à vers, venir, de* (preposition), *de* (partitive article), *en dans, par*. As there is no homology between French and English words, especially concerning prepositions, we give a partial translation of these words, assuming that the image will be an help to identify the correct meaning: *go, to, towards, come, from, of, in, in through*[5]. We notice that these words do not belong to the same grammatical category. The category is indicated by a colored frame: red for the verbs, blue for the names, and red and blue for the prepositions, as prepositions follow a verb and receive a name in French.

Certain features are drawn in several pictograms: for example, the arrow, which means a direction, can indicate a beginning *(to go, to come, from)*, a target (*to, towards*), or a path (*through*). As the language is anthropocentric, a figure of a person is added, in order to specify either the start of a movement or its end. We also give here a determination, indicated in French by the partitive article *de*, which is homonymous with the preposition *de* which corresponds to {*of, from, with*} in English. This determinant can be translated in English by *some*, or *any*, depending of the semantic type of the introduced entity.

As words are polysemic., it is possible to represent a same word by several pictograms, each one in a different semantic category, depending on the meaning of the polysemic word. It can be useful at the time the writer search the word he is thinking in a particular category, but it is not necessary, for it is only the word and not its meaning which is necessary to write the alphabetic text. As indicated above, pictograms are only a means to find words and their status is a new writing system.

Predicative structure given by the grammar

Grammar is cognitive and relies on an operator / operand structuration of the text, where operators can be verbs, adjectives, determinants, and/or prepositions.

For a given syntactic category, corresponding operations are proposed on the right part of the screen so that their structure is pre-defined in order to avoid a tiresome search of the main elements by the user. Figure 3 shows how operations on adjectives are proposed so that they can be easily found. On the center of the screen, we see a lexicon

[5] These prepositions are French prepositions; the translation does not cover exactly the same meanings in English.

area containing adjectives of color; on the left, there is a trace of the path in the hierarchies of pages; on the right column, we see possible operations on adjectives, for example: *switch to feminine; switch to plural; negation; switch to adverb; switch to a name; more; less; the most; the least ; enough; very*. It is possible to provide other operations, following the will of the user. Then, the problem is to choose which operations are useful enough to be on the same screen as the one of adjectives. The blank horizontal line below the lexicon area shows the selected pictograms. The grey line at the bottom gives the text produced by the language processing.

A similar arrangement of the screen can be built for verbs and nouns.

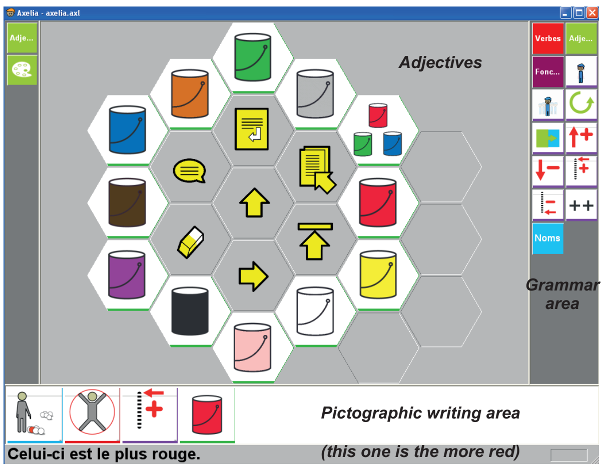

Figure 3: lexicon of adjectives of colours, with possible operations on the adjectives.

Augmentative pictographic writing

Instead of pictograms, it is possible to present the lemmatized words on a virtual keyboard, and to organize them either alphabetically or in micro-semantic fields. This presentation is similar to cases where the writer can read, but with a new option, which is to choose lemmatized words of the lexicon, and to manage the grammatical operations which process them in the sentence.

We can then extend the facilities to write offering two possibilities of assistance by EFS or by n-grams. This option is currently only under consideration. It depends on whether it improves writing or if it requires too much expertise compared to the usual scripture.

Discussion: AI, Cognitive Semantics and Computational Linguistics

We can analyze the two possibilities of assitance to write as two approaches: the first, concerning alphabetic writing, considers syntax and lexicon; the second one analyses the language in a more cognitive manner, considering grammar and semantic representations.

The alphabetic option can be called a mimetic linguistics: the NLP learns. It is powerful in case of repetitive structures in a given semantic domain, for example, in case of a job consisting of reporting in meteorology or any constraint domain. However the finite state automates can not process sentences of a certain complexity: in case of excessive complexity, we notice that the writers do not use the software.

In the case of n-grams, a limit of use is also noticed, maybe because of the dual task required for the assisted writing.

In the case of pictographic writing, if the pictograms refer only to concepts, the writer does not control the words that the N.L.P. makes him (her) use; what is produced is only roughly what (s)he wanted to write.

If the symbols represent a new writing, the difficulty lies in the representation and recognition of words figuratively or symbolically represented in a given semantic domain. Among the different meanings associated to a word, it is often the more concrete which is chosen between them, because it is the easiest to draw, and to recognize. A control assume that the best word chosen to match with the mental lexicon must be confirmed by training. In order to do so, we built a program which proposes pictograms and asks users to write what they think they mean. Then the answers are validated by statistics.

Finally, it all depends on what is expected of language processing. It is clear that the alphabetic option only reproduces texts already written, and that the pictographic option requests a special effort related to knowledge of vocabulary and grammatical operations, since the writer's awareness of these operations was often learned by imitation, although they have a proven cognitive relevance. The identification of words from pictograms also requires habituation, since the pictograms do not always represent the entities designated by the word. The syntax is shared between the writer who manages the word order, and the machine which automatically performs the morphological transformations: for example, concordance in gender and number, conjugations, prepositions, and grammatical times.

Conclusion: syntax, meaning and semantics

In each case of assisted writing text, the ease of writing is based on:

- The ergonomics of the human-machine interface presented and its adaptation to the associated device.
- The adequacy between the proposed method and the objective of the person who wants to write the text.

• The relevance of what is written compared to the text that the person has thought.
• Cognitive fatigue in management of dual tasks.
• The ease of correcting errors following the style of error.
• Concerning pictograms, a good organization of the lexicon which is presented, the pertinence of the pictograms, the easiness to find them in the semantic explored category, are necessary to facilitate writing.

Regarding the more general problem of NLP, we have presented a true issue instance, which includes allowing people to write a text like this one. Currently, only very simple texts are produced using such writing assistance. Measures of effectiveness must be defined and proven. They rely on: good writing, the time necessary to write what the user wants to write; visual and mental tiredness of the writer, as well as a general appreciation of comfort. Comfort is a subjective condition, depending of each person. In any case, a learning phase is always necessary in order to master a new technique. Several other problems relative to this new way of assisted writing are yet to be solved, but the whole system including gesture, virtual keyboard, arrangement of areas to compute the language, seems to be quite adequate to help communication. The effort concerns now the adaptation of the system to different disabilities in language, and to provide cognitive pictograms useful for teen-aged users with mental disability in order to facilitate learning a job, as gardening, woodwork, or catering, for example.

The adequacy of the Applicative and Cognitive Grammar seems to give quite good results in two cases, mental handicap of children, and paralysed and speechless people. The experience with children shows that they must strictly follow syntactic constraints given by the coloured frame which gives the syntactic category to order their words to build sentences. They are then able to produce messages, and to control with a vocal synthesizer that the result is the one they wanted. The reverse processing, which consists in translating alphabetic texts into pictographic scripture is also tested in our team, giving interesting results (Delamarre 2011). Concerning adults, an experience with a speechless patient helped him to recover sociability by “saying” what he wants.

We have given here a method to computerize French language. The method relies on description of French vocabulary and grammar. Until now, results have been obtained with children: they are able to write short French sentences from pictograms and to control their production with the vocal synthesizer. What they “say” concerns their life. It is encouraging because before, no one was able to know anything about them, given the lack of communication assistance. To readapt the processing in another language, it is necessary to reorganize grammar operations and to specify the types of words in the new language. We do not propose a universal language (Eco 1994), but a method that can be tested on other languages.

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References

Abraham, M.Y., 2007. “verbal polysemy in automatic annotation”, *20th international Conference*, Key West, Florida. FLAIRS.

Abraham M.Y., 2008. “Alteration in dialogical communication : the status of the language in the palliation of speech trouble”, *ICCTA*, Damas.

Abraham, M.Y., 2000a. « Reconstruction de phrases oralisées à partir d’une écriture pictographique », 883 :901, *Journal Européen des Systèmes Automatisés* (JESA) vol 34, n°6-7, Handicap 2000 – *Assistance technique aux personnes handicapées* –Hermès Sciences.

Abraham, M.Y., 2000b. « Reconstruction de phrases oralisées à partir d’une écriture pictographique », 883-901, *Journal Européen des Systèmes Automatisés* (JESA) vol 34, n°6-7, Handicap 2000 – *Assistance technique aux personnes handicapées* –Hermès Sciences.

Blache Ph., Rauzy S., « Le module de reformulation iconique de la Plateforme de Communication Alternative », *Atelier TALN’07 « Reconstruire la langue dans les communications alternatives avancées »,* Toulouse, 5-8 Juin 2007, vol 2 , 519-528.

Boissière Ph., Schadle I., Antoine J-Y., « A methodological framework for writing assistance systems: applications to sibylle and VITIPI systems », *Modelling, Mesurement & Control, Série C, (bioenginaring). Edited by Association for the Advancement of Modelling & Simulation Techniques in Entreprise, AMSE-journals* (Barcelona), Modellling C, Vol 67 (Supp Handicap 2006), 167– 176.

Delamarre, S. 2011. The utility of Combinatory Categorial Grammar in designing a pedagogival tool for teaching languages, Flairs 24.

Desclés, J.-P., 1990. *Langages applicatifs, langues naturelles et cognition,* Paris. Hermès.

Eco, U. , 1994.*La recherche de la langue parfaite dans la culture européenne*, Seuil.

Jackendoff, R., 1983. *Semantics and Cognition,* Cambridge, MIT Press.

Langacker, R. 1987.*Fondation of cognitive grammar*, vol 1. Standford University Press.

Pustejovsky J. ,1991. “The generative lexicon”, *Computational Linguistics*, vol. 17, n° 4.

Pustejovsky, J., 1995. *The generative lexicon*, Cambridge, Ma., MIT Press.

Vella F., Vigouroux N., « Layout keyboard and motor fatigue: first experimental results », *AMSE journal*, V. 67, 22-31, Avril 2007